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SUMMARY OF FINAL REPORT

Analysis of Survey Data

Summary by

Edward L. Hill
Project Leader

Operations Research Division

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Shelter Research 1100
Protection Studies
Subtask 1115A
Analysis of Survey Data

SUMMARY

OF

FINAL REPORT

1115A - Analysis of Survey Data

by

E. L. Hill, W. K. Grogan,

R. O. Lyday and H. G. Norment.

Prof. W. O. Doggett
(Consultant, N. C. State)

RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina

Analysis of Survey Data

I. SCOPE AND OBJECTIVES

This constitutes a summary of the final report (Reference 1) of the research completed by the Research Triangle Institute under OCD Project 1115A, Analysis of Survey Data. The OCD description for this project is as follows:

> "Review the National Fallout Shelter Survey findings to estimate probable error, or reliability in the light of existing experimental data and theoretical considerations. In consultation with the Subcommittee on Shielding of the Advisory Committee on Civil Defense, categorize the surveyed structures with respect to technical shielding characteristics, and evaluate the feasibility and importance of developing special computational programs for the several categories determined. Evaluate new information on shielding for application to the computation of protection factors for surveyed structures. Accomplish reprogramming or additional programming of computational procedures for analysis of the survey data."

The survey data requiring analysis under this project consist of many types of information collected, recorded, manipulated, summarized, and reported in Phases 1 and 2 of the National Fallout Shelter Survey (NFSS). Five million structures with potential shelter space were covered by the survey and data were collected in Phase 1 for approximately 375,000 of these. Over 600 architectural and engineering (AE) firms were responsible for collecting this mass of data in approximately six months' time.

The structures surveyed in the NFSS did not yield enough 100 PF or better spaces to shelter the nation's population. Allowing for population growth and movement between home and work, an additional 170 million shelter spaces will be needed by 1968 (Reference 2). This shelter deficit must be met by a combination of means, including improvement or new construction of subsidized and unsubsidized shelter space in privately owned facilities, shelters in federal civilian and military buildings, home shelters, and possibly reevaluation of structures rejected in the NFSS as below minimum PF standards.

NFSS procedures were generally designed to give conservative results, i.e., to underestimate the PF. It is expected that many additional adequate spaces could be identified if the computational procedures were made less conservative in order to yield results closer to the true PF.

The objectives of this project were to analyze the NFSS findings and to evaluate new information on shielding in order to identify feasible modifications of the NBS-NFSS Computer Program (References 3 and 4) leading potentially to additional shelter spaces in both existing and new structures with a very nominal expenditure of funds.

II. APPROACH AND FINDINGS

The OCD project description was divided into four tasks by the Research Triangle Institute. The four tasks were: (1) analyze the NFSS findings to determine probable error; (2) categorize surveyed structures with respect to technical shielding characteristics; (3) evaluate new information on shielding; and (4) recommend changes, when justified, to the computational procedures for analysis of the survey data. An outline of the approach used by RTI in accomplishing these tasks, plus another task added by OCD concerning trapped potable water, and major findings are as follows:

A. Analysis of NFSS findings

1. Introduction

RTI evaluated the NFSS findings to determine the probable error by surveying a probability sample of 33 buildings containing PF Category 2-4 shelters (see Table I). The primary objective of this survey was to determine what change in protection factor would occur if procedures, such as those of the Engineering Manual (Reference 5) were used in the NBS-NFSS Computer Program (References 3 and 4).

2. Procedural Differences

Using data collected by RTI, a Phase 1 FOSDIC (Film Optical Sensing Device for Input to Computers) form was prepared for each sample building and submitted to the National Bureau of Standards (NBS) for processing with the NBS-NFSS Computer Program. The results are reported as RTI FOSDIC (without partitions) PF's since the form was completed using Phase 1 instructions which required only that fire-break and load-bearing partitions be reported. Comparison of results from the RTI FOSDIC with the Engineering Manual computations indicates changes in computed protection factors due to procedural differences. The Engineering Manual computations for the sample buildings were an average of 110 PF units higher than the PF's calculated by the computer using the RTI FOSDIC.

3. Input Differences

A secondary objective of the survey was to determine the accuracy of the input data of the NFSS. This was necessary in order to estimate the reliability of future calculations using existing input data. Input differences were estimated by comparing the original AE-prepared NFSS Phase 1 FOSDIC (AE Phase 1) inputs and printout results with NBS-NFSS computations using data submitted by RTI on FOSDIC forms [RTI FOSDIC (without partitions)]. RTI data were obtained with more time and sources of data available than was the case of the NFSS. Comparison of these results indicated that the AE PF's

TABLE I

Sample of 33 NFSS Structures

Building Number	OCD Region	City	Standard Location	Facility Number	Address
1	1	Boston, Mass.	1315-0026	03130	30-32 North Bennet St.
2		Newark, N. J.	1541-0066	00984	73-77 Seventeenth Avenue
3		Bronx, N.Y.C.	1641-0046	00923	650 Grand Concourse
4		Bronx, N.Y.C.	1641-0138	03782	1235 Grand Concourse
5		Bronx, N.Y.C.	1641-0194	01907	81 West 182nd Street
6		Brooklyn, N.Y.C.	1642-0207	03232	5101-23 13th Avenue
7		Brooklyn, N.Y.C.	1642-0495	04335	485 Bedford Avenue
8		Manhattan, N.Y.C.	1644-0028	01072	304 Broadway
9		Manhattan, N.Y.C.	1644-0063	02527	435 Hudson Street
10		Manhattan, N.Y.C.	1644-0096	02947	300 Park Avenue
11		Manhattan, N.Y.C.	1644-0126	00858	362 W. 52nd Street
12		Manhattan, N.Y.C.	1644-0156	01917	327 W. 75th Street
13		Manhattan, N.Y.C.	1644-0204	03371	47-49 W. 129th Street
14		Manhattan, N.Y.C.	1644-0260	01773	360 Cabrini Blvd.
15		Queens, N.Y.C.	1645-0017	00764	4107 10th Street
16		Queens, N.Y.C.	1645-0538	07616	14415 Sanford Avenue
17		Rochester, N.Y.	1651-0005	00598	37-49 South Avenue
18	2	Washington, D. C.	2211-0005	00511	2700 Connecticut Avenue
19		Washington, D. C.	2211-0062	03448	18th and C Streets
20		Louisville, Ky.	2351-0029	01973	1011 W. Market Street
21		Cleveland, Ohio	2541-0058	01272	917 Euclid Avenue
22		Philadelphia, Pa.	2675-0017	01738	257 S. 16th Street
23	3	Memphis, Tenn.	3731-0043	01301	70 West E. H. Crump Blvd.
24	4	Chicago, Ill.	4121-0065	02101	3456 N. Damen Avenue
25		Chicago, Ill.	4121-0144	03302	320 N. Clark Avenue
26		Chicago, Ill.	4121-0490	06068	111 W. Jackson Blvd.
27		Chicago, Ill.	4121-0868	06023	10875-81 S. Racine Ave.
28		Indianapolis, Ind.	4241-0013	01003	604 E 38th Street
29	5	Houston, Texas	55B1-0026	06118	619 Main Street
30	6	St. Louis, Mo.	6434-0122	01971	1010 Pine Street
31	7	Los Angeles, Cal.	7231-0453	01427	403 West 8th Street
32		San Francisco, Cal.	7274-0072	05214	650 5th Street
33	8	Seattle, Wash.	8521-0061	01462	1215 4th Avenue

were an average of 22 PF units higher than those using the RTI FOSDIC. The AE Phase 1 PF results were higher than Engineering Manual results for four of the sample buildings and equal for three others. The positive bias is statistically significant at the 10 percent level; the important conclusion is that AE data collection procedures led to overestimated PF's using the NFSS Computer Program.

Statistics of individual input differences are tabulated in Reference 1. As examples of specific data input differences, AE data inputs for upper wall mass thickness were an average of 21 psf higher than RTI estimates and the first floor mass thickness was an average of 15 pounds per square foot (psf) higher. Because of NFSS instructions, it was expected that the AE's would be conservative when evaluating building data. Consequently, the observed data input differences were surprising.

4. Experimental vs. Calculated PF's

As a part of this task, analysis of NFSS findings, an evaluation of the accuracy of the Engineering Manual procedure was made by comparing theoretical results with published experimental results using the "pumped source technique" and full-scale buildings. A comparison was made for four buildings, and the results showed the Engineering Manual to be conservative by as much as a factor of 2. Modest weight, equivalent to 20 percent, or less.of the exterior wall mass thickness, assigned to interior contents would make the results agree.

5. Overall NFSS Probable Error

A measure of the total probable error in the NFSS is the comparison of the original AE Phase 1 FOSDIC results with Engineering Manual PF's based on RTI input data. This comparison indicates that the AE Phase 1 results are conservative by an average of 99 PF units per building without consideration for interior contents.

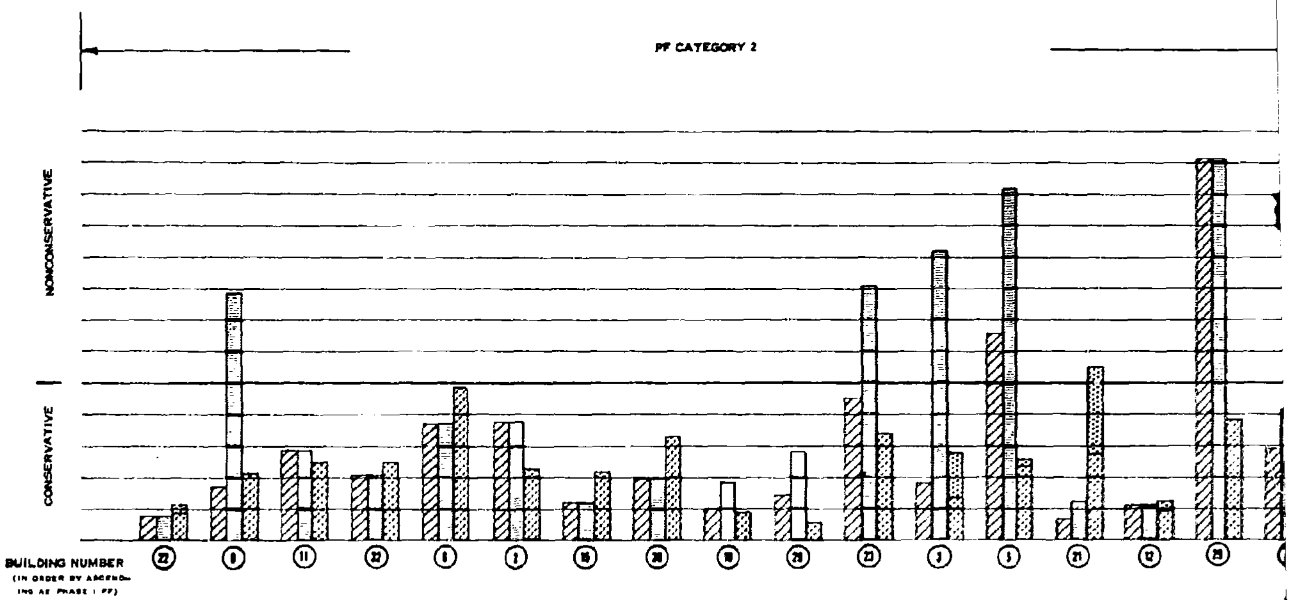
A comparison of the AE Phase 1 and 2 PF's, RTI FOSDIC PF's, and Engineering Manual PF's for each of the 33 sample buildings is presented in Figure 1.

6. Impact of NFSS Errors on Other CD Activities

Although beyond the scope of this study, the impact of the probable errors of the NFSS findings on other Civil Defense activities is recognized. These errors are of great significance to those using these PF estimates in vulnerability analyses and related areas of study (need for decontamination, need for additional shelter or shelter modifications, speed of radiological recovery, etc.).

FIGUR

Comparison of 33 Sa



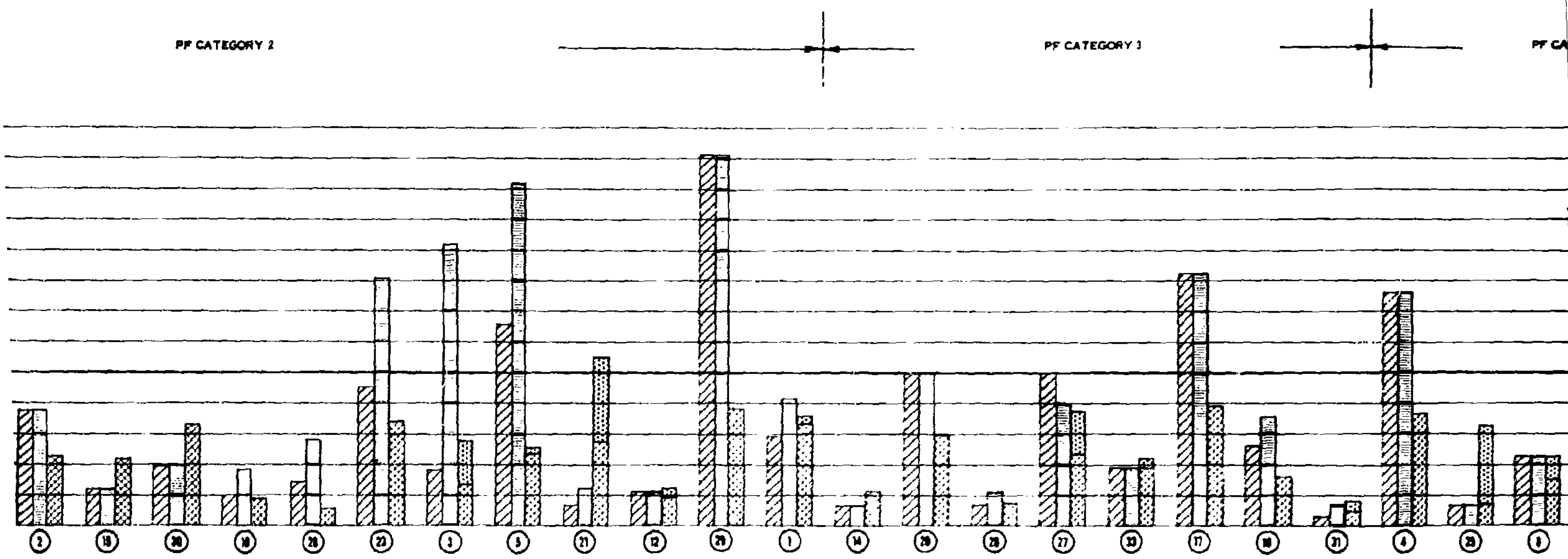
1

BUILDING NUMBER	1	2	3	4	5	6	7	8	9	10	11	12	13
ENGINEERING MANUAL PF	116	59	164	66	45	65	147	278	125	275	73	252	373
AE PHASE 1 PF	67	50	53	100	59	48	140	115	42	53	42	43	250
AE PHASE 2 PF	96	50	300	100	100	44	200	125	198	100	42	43	250
RTI FOSDIC (WITHOUT PART 2 DATA) PF	77	31	43	45	21	63	67	83	53	48	36	53	51
RTI FOSDIC (WITH PART 2 DATA) PF	83	–	31	–	23	–	–	125	–	–	–	73	–

* BUILDING NUMBER 24 NOT INCLUDED – ACCESS DENIED.

FIGURE I

Comparison of 33 Sample Building PF's*

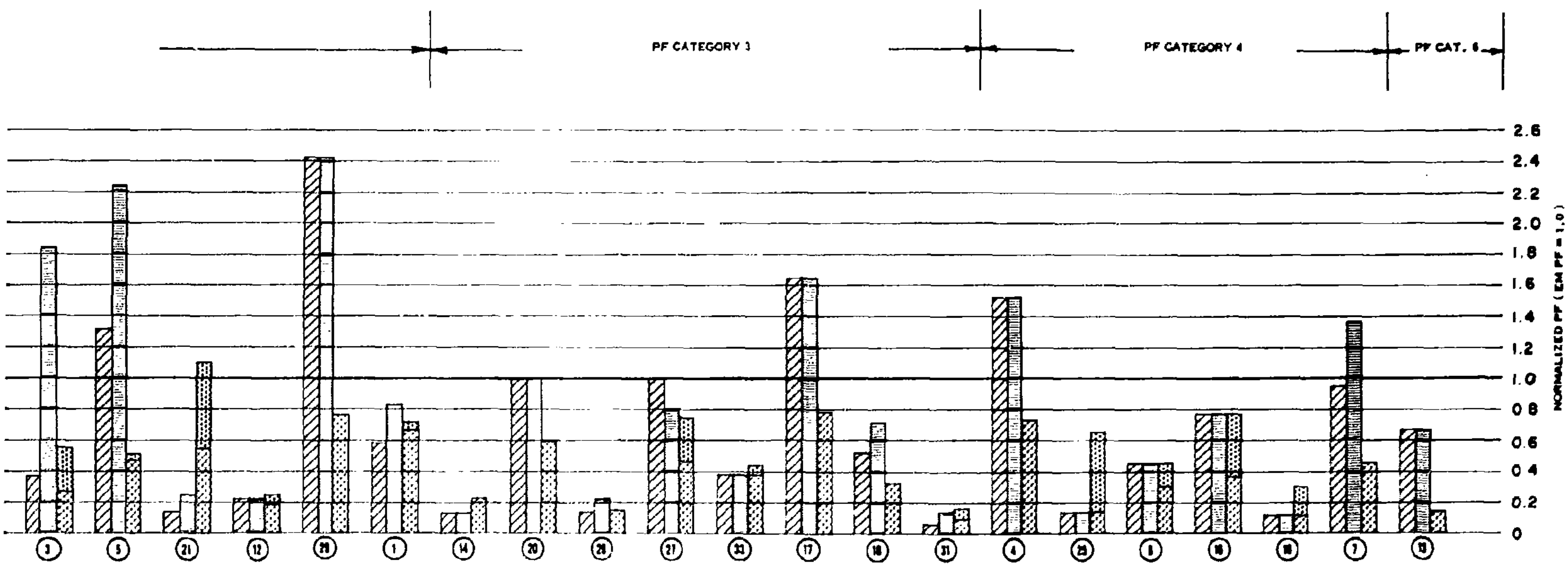


JMBER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
MANUAL PF	116	69	164	66	45	65	147	278	125	275	73	292	379	556	212	[illegible]
PF	67	50	59	100	59	48	140	125	42	53	42	63	250	71	50	125
PF	96	50	300	100	100	48	200	125	196	100	42	63	250	71	50	125
(WITHOUT PARTITIONS) PF	77	31	43	45	21	63	67	83	53	48	36	53	53	110	91	53
WITH PARTITIONS) PF	83	–	91	–	23	–	–	125	–	–	–	71	–	125	–	125

JMBER	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
MANUAL PF	[illegible]	164	1280	71	455	[illegible]	62	–	[illegible]	550	71	185	26	127	1250	100
PF	[illegible]	[illegible]	125	71	53	42	56	–	100	[illegible]	71	53	63	50	77	42
PF	[illegible]	[illegible]	125	71	110	42	[illegible]	–	100	[illegible]	56	104	63	50	170	42
(WITHOUT PARTITIONS) PF	37		125	42	250	43	42	–	110	83	33	20	20	83	[illegible]	50
WITH PARTITIONS) PF	37	53	330	–	500	56	–	–	500	–	53	20	–	–	200	–

FIGURE 1

rison of 33 Sample Building PF's*



5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
85	65	147	278	125	275	73	292	379	556	212	161	47	164	1080	71	455	450	62	–	770	550	71	185	26	127	1250	100	189
59	48	140	125	42	53	42	63	250	71	50	125	77	77	125	71	59	40	56	–	100	71	71	53	63	50	77	42	71
30	48	200	125	196	100	42	63	250	71	50	125	77	120	125	71	110	43	100	–	100	120	56	104	63	50	170	42	71
21	63	67	83	53	48	36	53	53	110	91	59	37		125	42	250	43	42	–	110	83	33	20	20	83	110	50	71
23	–	–	125	–	–	–	71	–	125	–	125	37	53	330	–	500	58	–	–	500	–	53	20	–	–	200	–	83

B. Categorization

The categorization of surveyed structures with respect to shielding characteristics was based on a statistical sample of 1541 buildings drawn from the more than 300,000 buildings surveyed in the NFSS Phase 1. The sample was selected from the NBS Phase 1 M1 and M2 files; statistical studies on detailed structural properties were made using the IBM 7090 Computer at the National Bureau of Standards. Statistical tabulations were prepared relating protection factor to the number of shelters and buildings falling within selected incremental ranges of properties such as story number, percent apertures, contaminated plane width, floor area, basement exposure, dose source, and others. The detailed structural input data and PF output data for the sample of 1541 buildings are available on magnetic tape for any additional categorization which may become desirable.

For this sample of buildings, 39 percent of the shelters (shelter areas) are in the basement. The mean story number varies from three to four for all PF categories except Category 8, where it jumps to six. The average percent of apertures for buildings in each PF category ranges from fifteen to nineteen percent and for shelters never exceeds twenty-five percent. The vast majority of the shelters, 78 percent, have an area in the range of 1,000 - 10,000 square feet. Only seventeen percent of the total shelters have interior partitions reported. The modal value of the exterior wall mass thickness falls in the range of 100 - 150 psf. Eighty percent of the sample buildings have only one part reported, 12 percent have two parts, and four percent have three parts.

C. Research Review

This task was accomplished by visits to contractors engaged in shielding research, by personal contacts, and by a literature search. The objectives of this task were to determine whether existing methods for computing protection factors need modification to agree with new data, to recommend new investigations in areas where gaps exist in current shielding knowledge, and to suggest applications of new shielding information.

Major findings of this review of shielding research were:

1. The roof contribution and infinite field contribution predicted by the Engineering Manual method for a concrete block house have been experimentally confirmed.
2. The dose rates from finite planes of contamination indicate that the NFSS Computer Program and AE Guide (Reference 6) need revision.

3. Experimental dose rates in unexposed basements are higher than predicted by the Engineering Manual.
4. Measurements of dose angular distributions support the use of an "effective height" in treating ground roughness.
5. A new procedure based on experimental results is available for calculating ceiling shine separately from skyshine. This will improve calculations for certain building configurations (see recommendation 1. f.).
6. The Engineering Manual method of azimuthal sectors is adequate for handling interior partitions.

D. NBS-NFSS Computer Program Modifications

The results of the preceding tasks identified and justified feasible modifications to the NBS-NFSS Computer Program. Recommendations for changes in the machine method of calculating contributions are made for exposed basements, roofs, stories above grade, and areaways. Revised area factors (defining the fraction of a story offering protection greater than a predetermined value) and a method for considering the effect of interior partitions are also recommended. These changes bring the NBS-NFSS Computer Program closer to Engineering Manual procedures while still using only data collected in Phases 1 and 2 of the NFSS.

E. Survey of Available Potable Water

Although not one of the four major tasks, OCD asked RTI to obtain information on the amount of potable water "trapped" by plumbing, holding tanks, etc., in the 33 building sample used to study other NFSS characteristics. All drinkable water that was contained and covered (i.e., suitable for drinking in a fallout situation) was recorded. An average of 2.96 gallons per PF Category 4-8 shelter space was found. Seventeen of the buildings contained sufficient trapped water to supply the shelter for a 14 day period (3.5 gallons per person) without stocking of water containers.

III. RECOMMENDATIONS

A. Follow-up Work by RTI

The following would normally be recommendations; however, the need for this work has already been recognized by OCD and a follow-on contract has been negotiated for OCD Subtasks 1115B and C. The project statements therein are as follows:

Subtask 1115B

"Analyze Phase 2 data from the NFSS to indicate relative importance of shielding characteristics in order to improve PF calculations and to indicate the most important modifications to improve PF. Utilize the

data and studies of recurring types of key facilities under various geographic and construction conditions to identify the most critical engineering characteristics of the structure which would require modification for occupancy and operation in a fallout situation. Incorporate PF computational procedures for special characteristics of these key facilities in the electronic computer program."

Subtask 1115C:
"Evaluate information on shielding, such as the effect of interior partitions, ground roughness, finite planes, apertures, ceiling shine, basement exposure, etc., for application to the computation of protection factors."

Additional analysis of area factors (defining the fraction of a story offering protection greater than a predetermined value) will be made under Subtask 1115B because present area factors ignore the roof contribution.

B. Recommendations

The following recommendations do not fall within the scopes of work described above.

1. Action Recommendations

a. The NBS-NFSS Computer Program should be modified to bring it more in line with Engineering Manual procedures using NFSS Phases 1 and 2 data.

b. If collection of more complete building data than collected in the NFSS Phases 1 and 2 is justified, a modification of the NBS-NFSS Computer Program should be made to utilize the azimuthal sector procedure of the Engineering Manual.

c. Data collection in any NFSS updating procedure should make full use of building plans.

d. "Technical Operations Research" of Burlington, Massachusetts, should compare their finite contaminated plane data (Reference 7) with Engineering Manual calculations to verify Chart 9 therein.

e. The next revision of the AE Guide should carry the instruction for interior partitions: "The proper interior mass thickness X_i depends on the partition configuration. For box and corridor geometries, use a mass thickness equal to the interior wall thickness. For compartment geometries with corridor mass thickness X_c and cross-partition (partitions perpendicular to the wall whose contribution is being considered) thickness X_p, use $X_i = X_c + 1/2\ X_p$." However, see recommendation 2. d.

f. Present Engineering Manual procedures, which consider ceiling shine as a part of skyshine, are nonconservative when a large part of the

skyshine contribution is shielded. In the RTI survey of 33 buildings, almost every building had a portion of the skyshine shielded and some had complete shielding. The "Technical Operations Research" procedure for computing ceiling shine (Reference 8) should therefore be incorporated in the Engineering Manual. This procedure would be used for computing the PF on an intermediate floor in a tall building with a large fraction of apertures, thick floors, and where a significant part of the skyshine is shielded.

2. Research Recommendations

   a. Penetration data such as that presented in the charts in the Engineering Manual should be developed for the radiation of cobalt-60 and attenuation characteristics of steel. This will enable small-scale model structure experiments to be more precisely related to full-scale buildings exposed to fallout radiation.

   b. The experimental dose rate measurements in a "Technical Operations Research" model basement were higher than calculated by the Engineering Manual method and the dose rate first increased with depth, then decreased, contrary to calculations. It is therefore recommended that an experimental and theoretical investigation be made of the ground contribution to an unexposed basement.

   c. The RTI analysis of 33 NFSS buildings using the Engineering Manual required the use of many off-center azimuthal sectors. The Engineering Manual method predicts that an off-center azimuthal sector will give the same dose as a centrally located sector of the same size with the same contaminated plane projected dimensions. It is recommended that an investigation be made of the influence on the wall barrier factors of slant penetration of radiation through walls in off-center azimuthal sectors.

   d. The research review conducted by RTI has not revealed any work in determining the effect of the exterior wall on the interior wall barrier factor when $X_e + X_i$ is greater than 100 psf. It is therefore recommended that the interior partition barrier factor for box-type interior partitions of thicknesses 20, 40, 60 psf in a building with 80 psf exterior walls be measured to determine the influence of the wall on the partition barrier factor.

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